EXECUTIVE SUMMARY

CAMPAGN 2019

PAR

LE CONSEIL SCIENTIFIQUE DE LA COMMISSION INTERNATIONALE

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MONITORING LAKE GENEVA

The physicochemical analyses of the lake water, including micropollutants, as well as the biological monitoring, are achieved at the lake's deepest point, designated SHL2.

1. PHYSICOCHEMICAL QUALITY AT SHL2

The year 2019 was hot: with 2011 it was the third hottest year observed since 1980. Exceptional temperatures were for the most part recorded in February and March and then from June to the end of the year. Radiation was also particularly high for most of the year, making 2019 the second highest year for energy flow absorbed by the lake for the 1981–2019 period. These meteorological conditions produced higher water temperatures than average and disrupted winter mixing, which extended to only 135 m. Therefore, the deep layers could not be reoxygenated and the oxygen concentrations at 309 m remained lower than 4 $mgO_2.L^{-1}$ throughout the year. High spring temperatures also impacted perch reproduction phenology.

Chloride concentrations seem to have stabilised since 2016. In 2019, the mean total nitrogen concentration (667 µgN L^{-1}) decreased compared to 2018, while remaining close to the value measured in 2017. The mean annual nitrogen concentration (542 µgN L^{-1}) continued to drop.

Total and dissolved phosphorus concentrations were clearly lower than in 2018. With mean weighted concentrations at 16.20 µg L^{-1} and 11.91 µg L^{-1}, respectively, these concentrations again illustrate the prolongation of a declining trend interrupted in 2018.

2. BIOLOGICAL MONITORING OF THE PELAGIC ZONE (SHL2)

The changes in the Brettum Index, established based on the taxonomic composition of the phytoplanktonic community, indicate that the impact of decreasing phosphorus concentrations remains substantial. During the summer and autumn, the picocyanobacteria biomass can equal or even surpass the biomass of nano- and micro-phytoplankton. This phytoplanktonic group tends to be promoted by the reduction in phosphorus concentrations and the lake's heating. In winter, the biomass of certain filamentous species such as Planktothrix rubescens (cyanobacterium) and Mougeotia gracillima (Conjugatophyceae) were high. Despite a reduction in phytoplanktonic productivity in spring, the mean annual phytoplanktonic biomass remained high (1515 µg L-1), higher than the objective set by the CIPEL for the current plan (1000 µg L-1).

The zooplanktonic community has shown lesser abundance since the end of the 1980s. The continuous reduction of the abundance of zooplankton remains mainly due to a decline in daphnia; in 2019 the lowering trend observed over the past few years in the Leptodora and Bythotrephes cyclopoids was sustained.

The diet of the cladocerans continued to be dominated by daphnia, Bythotrephes and Leptodora. The relative contributions of these prey to the food bowl showed strong seasonality that recurred from one year to the next. In 2019, spawning began earlier than in 2018. Cladoceran reproduction data collected during the 2018–2019 winter should be considered cautiously because of the low number of individuals sampled and the weather conditions, which limited the number of samplings.

3. MICROPOLLUTANTS IN RHÔNE RIVER AND LAKE GENEVA WATERS (SHL2)

One hundred sixteen crop protection products, thirty-four pharmaceutical active ingredients, two anti-corrosion agents and four organic composites (1,4-dioxane, methyl tertbutyl ether [MTBE], benzidine and its metabolite 4-aminobiphenyl) were analysed in the Rhone River waters and upstream of Lake Geneva throughout 2019. Except for a peak in the amidosulfuron concentration in March, no plant protection product surpassed the requirements of the Ordonnance sur la protection des eaux (Ordinance on water protection), i.e. 0.1 µg L^{-1}. Of the 34 pharmaceutical active ingredients examined, some were found in the Rhone River waters at concentrations that remained high. A maximum of 1.3 µg L^{-1} was measured for metformin (mean, 0.43 µg L^{-1}); guanyl-urea (the main metabolite of metformin) peaked at 2.94µg.L^{-1} (mean, 1.24 µg L^{-1}).

In terms of annual flows, the total quantities of plant protection products discharged by the Rhone to the lake in 2019 totaled 280 kg (versus 308 kg in 2018, 444 kg in 2017 and 577 kg in 2016). Industrial pharmaceutical active ingredients decreased to 132 kg $year^{-1}$ (versus 341 kg in 2018 and 672 kg in 2017). The 1,4-dioxane load, estimated at 182 kg $year^{-1}$, is progressively lowering (345 kg in 2018, 6 tonnes in 2014).

Monitoring micropollutants in Lake Geneva waters includes surveillance of 381 pesticides, 66 medicinal product residues and 5 metals (total and dissolved) from the surface to the bottom as well as the surveillance of manganese at the lake bottom.

The purpose of this programme monitoring the water quality of Lake Geneva is essentially one of monitoring drinking water.

The pesticide and metal contents satisfy the requirements for drinking water as stipulated by Swiss and French legislation as well as the threshold values for environmental protection.

For medicinal residues, azithromycin, clarithromycin and diclofenac were measured at the threshold value defined in Swiss legislation. The presence in the environment of these medicinal residues is nonetheless undesirable, notably in water intended for drinking water, as is the case of Lake Geneva waters. Metformin was measured between 0.40 and 0.61 µg L^{-1} at 15 m deep and 0.21–0.51 µg L^{-1} at 100 m, indicating that its level is stabilising, even lowering after a relatively continuous rise since 2014. The concentrations in guanylurea oscillated between <0.05 and 0.34 µg L^{-1}.

SPECIFIC STUDIES

1. HYDROPHOBIC MICROPOLLUTANTS IN TRIBUTARIES

Monitoring hydrophobic pollutants (polychlorobiphenyls [PCBs], polybrominated diphenyl ethers [PBDEs] and polycyclic aromatic hydrocarbons [PAHs] was initiated in 2018 in the rivers of Lake Geneva's basin with passive sensors. This was done to obtain an overall homogenous view of the presence of these micropollutants and to estimate the concentrations and weighted loads over time of these micropollutants. The first campaign (autumn 2018, carried out on 46 sites) identified the portions of water bodies presenting the highest concentrations and loads of PCBs, PBDEs and dissolved PAHs. To confirm the trends observed in 2018 and provide additional information on the sources of potential pollutants, a second campaign was conducted in spring 2019 on 32 sites. To acquire greater knowledge on the distribution of hydrophobic pollutants between the dissolved phase (sampled with sensors) and the particulate phase, data on the concentrations in suspended matters (SMs) were also acquired on two sites by deploying SM traps.

As in 2018, it was shown that the load of these dissolved pollutants arriving in Lake Geneva is mainly due to the Rhone River, which in 2019 accounted for 76% of the PCBs, 77% of the PBDEs and 86% of the PAHs. The PCB, PBDE and PAH loads in the Arve River accounted for 33%, 25% and 36%, respectively, of those stemming from the Rhone after their confluence at Geneva. High concentrations were measured during one of these two campaigns at the Nant d'Avril River, the Vengeron, the Venoge, the Chamberonne, the Arve (Passy) and the Rhône (Evionnaz) for PCBs and PBDEs, as well as the Eau Froide de Roche for PBDEs. Similarly, high PAH concentrations were sampled in the Vengeron, the Nant d'Avril and the Chamberonne rivers.

These two campaigns provide a database making it possible to define a regular monitoring protocol of the tributaries and to detail whether the lake plays a role of sink (or even of source) for these pollutants.

2. PRELIMINARY STUDIES ON MICROPLASTICS

Microplastic pollution is a source of growing concern because of their potential impacts on ecosystems and human health. Over the past few years, it has been established that microplastics are present in all aquatic ecosystems (rivers, lakes, seas and oceans) including Lake Geneva and its tributaries. Within the assessment of microplastic pollution in Lake Geneva, the present study aimed to identify their presence in the digestive system of the lake's fish as well as in the Rhone and Versoix river waters.

The presence of microplastics was inventoried in 103 digestive tracts of several fish species sampled in Lake Geneva by professional fish harvesters. The species chosen included both carnivorous fish, among the lake's most widely consumed fish, and planktivorous and omnivorous fish. In addition, a sample of lake water and six samples of river water subjected to more or less pronounced urban discharges were analysed.

A total of 16 particles of plastic >500 µm were identified in ten of the 103 fish analysed, accounting for 9.7% of the individuals studied. A rate of 80% of these particles were identified in the digestive tracts of common roach (*Rutilus rutilus*) and burbot (*Lotta lotta*). Microplastics were detected throughout the water samples analysed. The concentrations in microplastics >500 µm measured in the water varied between 0.02 and 0.11 particles/m^3 and between 0.17 and 0.38 particles/m^3 for microplastics >100 µm.

These results demonstrate a relatively limited contamination of the river waters analysed in this study. The lake's fish populations also seem contaminated at a low level by microplastics >500 µm in size. Supplementary investigations on smaller particles are planned.

3. MACROPHYTES

In 2019, a campaign sampling Lake Geneva's macrophyte population was carried out to analyse the qualitative and quantitative progression of macrophyte communities. In a context of progressive warming of the lake's shallow waters observed since 1973, the coastal zone is characterised by progression in species distribution. It can be noted that the collections of large species has prospered to the detriment of small species which are confined to small areas. The breadth of flora at the Lake Geneva scale remains comparable to the variety found in 2009. The macrophyte group generally reached the limits of the top-bed, within the ranges of maximum colonisation depths that spermaphytes can reach, as reported in the literature (814 m), generally progressing compared to 2009. Comparing relative abundance in the historical references from 1975 to 2019 demonstrates (1) continual regression of *Stuckenia pectinata*, an indicatory species of an alteration of water quality, which prospered in Lake Geneva at the beginning of the 20th century when water quality improvement measures were initiated. (2) At the same time, progression of *Chara denudata* seems to indicate that the water quality of Lake Geneva is improving. The large underwater grass beds of *S. pectinata* are progressively being overtaken by aquatic grass beds of *Potamogeton perfoliatus* and *Myriophyllum spicatum*. The collections of Characeae have regressed compared to the 2009 collections. This regression probably originates from substantial spatiotemporal variability, which is difficult to demonstrate in a 10-year monitoring period. Within a context of warming shallow waters, it is possible that over the long-term modifications of macrophyte communities in favour of more thermophilic species will be observed.

4. EXOTIC INVASIVE SPECIES

Since the beginning of the 20th century, benthic invertebrate communities of Alpine lakes have changed following the intake/flux of new species coming mainly from Ponto-Caspian, Asian and North American areas. More than 15 species of aquatic macroinvertebrates have colonised Lake Geneva. Nearly half of them come from the Ponto-Caspian region. Monitoring was set up as early as 2003 to detect their arrival and assess their relative abundance. A high risk of ecological and/or socio-economic impacts exists for four mollusc species: the New Zealand mud snail (*Potamopyrgus antipodarum*), zebra mussels and quagga mussels (*Dreissena polymorpha* and *D. rostriformis bugensis*), the Asiatic clam (*Corbicula fluminea*) and three species of shellfish: the killer shrimp (*Dikerogammarus villosus*), the Caspian mud shrimp (*Chelicorophium curvispinum*) and the bloody-red mysid shrimp (*Hemimysis anomala*). Since around 2003, the bottom of the coastal areas have been modified with the installation of the killer shrimp, the Asiatic clam (2008) and the Caspian mud shrimp (2010), and finally the quagga mussel (2015). The coastal biodiversity of the endogenous species has been in rapid decline since the beginning of monitoring, with a decrease in biomass of the large mussels of the Unionidae family, the indigenous gammarid, the waterlouse and the biodiversity of insect larvae.

5. SITUATIONAL ANALYSIS OF THE QUAGGA MUSSEL (DREISSENA ROSTRIFORMIS BUGENSIS)

The first observations of *D. rostriformis bugensis* (the quagga mussel) in Lake Geneva dates back to 2015, in the Vaud canton. Since then this species has tended to overtake the zebra mussel (*D. polymorpha*), which was introduced earlier: 80% of the mussels collected on the top-bed during the macrophyte study are made up of quagga mussels. The species is now present throughout the lake.

The veliger larvae of the two *Dreissena* species are too similar to be distinguished. However, the analysis of the phenology of the veliger larva collected with zooplankton indicates seasonality marked by high abundance in summer; since 2017 these larvae have also been present in significant numbers during winter. This change in the phenology of veliger larvae is an indication of the lake's colonisation by quagga mussels. With its capacity to establish at greater depths (up to 80 m), this species currently raises serious problems for water pumping management services by obstructing water intake structures (drinkable, cooling water, etc.). Moreover, its ability to filter great volumes of water has positive consequences on the water transparency but also results in risks of reducing the planktonic biomass in the zones where it proliferates.